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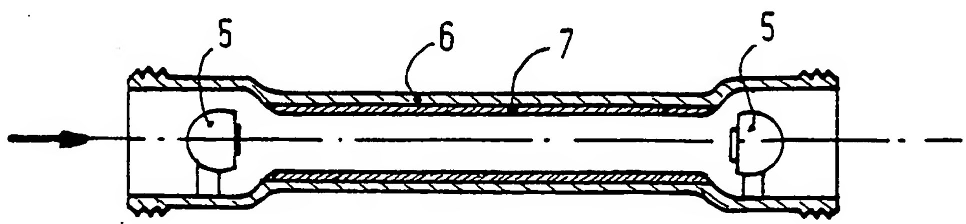

(57) Abstract

A transducer for use in an ultrasonic flow meter operating in accordance with the phase difference measuring principle or the transit time difference measuring principle, in which the transducer surface has raised and/or recessed portions of such shape and dimensions that a quenching pattern is imparted to the sound waves reflected from the transducer surface, which quenching pattern prevents the occurrence of objectionable echoes on an opposite transducer. An ultrasonic flow meter including such transducers is so arranged that sound waves directed towards the wall of the flow meter are absorbed and/or quenched.

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Transducer with reduced acoustic reflection.

The invention relates to a method of reducing undesired echos in ultrasonic flow meters operating in accordance with the phase or transit time difference measuring principle.

The types of ultrasonic flow meters that operate in accordance with the phase or transit time difference measuring principle are often built up of two transducers mounted in spaced-apart, facing, parallel relationship and a calibrated measuring tube between these transducers. The fluid to be measured flows past the transducers and through the measuring tube. An ultrasonic sound beam travelling downstream is seemingly accelerated while an ultrasonic sound beam travelling upstream is seemingly delayed. By transmitting a short duration sound beam concurrently via each one of the two transducers and, briefly thereafter, receiving the sound beams via these transducers as they arrive there, the flow velocity of the fluid can be derived from a measurement of the phase or transit time difference between the received sound beams.

Self-evidently, the period of time during which the two sound beams are transmitted must not exceed the time required for reaching the opposite transducer as the latter should then be switched to operation as a receiver. Consequently, the measurement extends over a very brief

period of time. To achieve sufficient accuracy of the measurement, the procedure of transmitting and receiving is repeated continuously at an optimally high repetition rate.

However, when doing so the following problem is encountered: when receiving, the transducers reflect part of the sound energy back into the measuring tube. This reflection effect is apt to repeat itself. The resultant echos will mix with the signals to be measured and measuring errors will result therefrom, thereby reducing the accuracy of measurement of the present-day ultrasonic flow meters operating in accordance with the aforesaid principle.

The first object of the present invention is to prevent the occurrence of such undesired echos or to at least so reduce such echos that their effect is negligible. In accordance with the invention, this object is achieved as the active surface of each of the transducers is provided with one or more raised or recessed portions, as a result of which such a quenching pattern is introduced into the reflected sound by interference that no or substantially no echo is incident upon the opposite transducer. Steps have to be taken, however, to prevent the side lobes formed by this reflection effect from reaching the opposite transducer due to, for example, reflections against the inner wall of the measuring tube.

Some examples of the effect of a transducer provided with a raised portion in accordance with the invention on

the pattern of a reflected, planar ultrasonic sound beam are shown in Figs. 1-4. The outlines drawn in these Figures are each time lines of equal sound intensity 2, while the wavelength of the sound in the fluid to be measured is λ.

In Fig. 1, the reflecting transducer 1 is flat and causes the normal reflection pattern.

In Figs. 2 and 3, the transducer is provided with a raised portion 3 of a height 1/4 λ, with a varying $\frac{d}{D}$ ratio. A quenching region is formed above the edge of the raised portion by interference. The waves reflected from face 4 have to travel a distance that is 2 x 1/4 λ= 1/2 λ greater than the waves reflected from the face of raised portion 3. Consequently, the first-named waves lag 180° in phase behind the last-named waves; local quenching occurs as a result of the mixing of two kinds of waves.

The shape of this quenching region can be altered by changing the $\frac{d}{D}$ ratio but also, as shown in Fig. 4, by changing the height h. Accordingly, the most favourable dimensions of the raised portions of the flow meter structure according to the invention can be determined by calculation and experiment. It is observed in this respect that, self-evidently, the freedom to choose the dimensions in question is limited by the fact that each transducers is also used as a transmitter and the transmit characteristic is determined, inter alia, by the shape of the, then emissive, surface of the transducer. Practice has shown

that favourable results are achieved when ratio $\frac{d}{D}$ is in the range of from 0.3 to 0.7.

It is emphasized that, instead of the raised portions shown in the Figures, also recessed portions in the transducer surface may be used to achieve similar effects. Moreover, the raised or recessed portions may have shapes other than those shown in the Figures, for example annular shapes, while the raised or recessed portions further need not have the same dimension h over the entire surface.

The total amount of reflected sound energy is not affected by the above steps. The reduction of the reflected sound intensity in the centre axis of the transducer results in an increase in the reflected sound intensity at the edge thereof, i.e., the formation of side lobes. Accordingly, there is a danger of the relatively energy-rich side lobes reflecting from the wall of the measuring tube to so disturb the measuring signal.

A second object of the present invention is therefore to prevent the occurrence of objectional reflections of the side lobes from the wall of the measuring tube. To this end, the tube wall is internally coated with a layer of a material in which the sound propagates at a velocity that is approximately equal to or smaller than the sound velocity in the fluid to be measured and which exhibits a relatively high internal damping. When the fluid to be measured is water, a suitable material is, for example, a synthetic material called polysulfon.

Some embodiments of a flow meter in accordance with the invention are shown in Figs. 5,6,7 and 8, all based on though not limited to a previous patent application to the same inventor.

The embodiment of Fig. 5 comprises a sleeve 6 in which the transducers 5 are mounted in enlarged sections thereof. Transducers 5 have active surfaces provided, in accordance with the first part of the present invention, with, in this embodiment, raised portions for preventing undesired echos in the axial direction of the measuring tube 7. This measuring tube 7 is formed by an inner coating on sleeve 6 and is of a material in which sound propagates at a velocity that is approximately equal to or smaller than that in water and which exhibits an optimally high sound damping. This material may be, for example, the aforesaid polysulfon, in which the sound velocity is approximately 1880 m/s while that in water is approximately 1480 m/s. The critical angle for incident sound water/polysulfon is hence very small, so that practically all sound incident at an angle upon the coating penetrates into the polysulfon and is absorbed there for the greater part. None or only a minor part of this obliquely incident reflection sound from the side lobes will therefore reach the opposite transducer, so that this reflection sound has no or only a negligible effect on the measuring process.

Another embodiment is shown in Fig. 6. The distance between each of the transducers and the associated end of

the inner coating 7, which coating is identical to that of Fig. 5, is made so large that the side lobe sound 8 is not incident upon this coating and dies in the spaces 9.

A further embodiment is shown in Fig. 7. The inner coating or measuring tube 7 is mounted loose within sleeve 6 and is centred therein by means of the centring shoulders 10 of the transducers 5.

In this manner, a perfect concentric transmission of the sound within measuring tube 7 is ensured, which enhances the accuracy of the measurement even at very low flow velocities. In the embodiments of Figs. 5 and 6, several tolerances play a part in this concentricity. Measuring tube 7 has its opposite ends provided with apertures 11 through which the fluid to be measured flows into and out of the tube. A seal 12, such as an O-ring, is operative as a partition separating the entrance and the exit of the flow meter.

Finally, the embodiment of Fig. 8 is an ultrasonic flow meter that is made entirely of a material having the acoustic properties required for measuring tube 7 of Figs. 5-7. It is possible to use this material for the entire meter if no strong, for example metallic, sleeve 6 is required. Self-evidently, hybrids of the embodiments of Figs. 5-8 are possible, for example embodiments having metallic connecting pieces.

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* C L A I M S *

1. A transducer for ultrasonic flow meters operating in accordance with the phase or transit time difference measuring principle, characterized in that the transducer surface against which reflection takes place includes raised and/or recessed portions of such shape and dimensions that a quenching pattern is imparted to the sound waves reflected from said surface, which quenching pattern serves to fully or practically fully prevent objectionable echos on the opposite transducer.

2. A transducer according to claim 1, characterized in that the difference in height between the raised and/or recessed portions of the transducer surface against which reflection takes place is in the range of from 1/4 λ to 1/8 λ, in which λ is the wavelength of the sound in the fluid the flow velocity of which is to be measured.

3. A transducer according to claims 1 and 2, characterized in that the active surface of the transducer is circular and includes a raised or recessed portion that is concentric therewith.

4. A transducer according to claim 3, characterized in that said concentric, circular raised or recessed portion has a diameter that is between 0.3 and 0.7 times the diameter of the total surface against which reflection takes place.

5. An ultrasonic flow meter operating in accordance

with the phase or transit time difference measuring principle, which meter includes transducers in accordance with claims 1-4, characterized in that means are provided for preventing the side lobes formed by the interference of the reflected ultrasonic sound signal from adversely affecting the accuracy of the measurement.

6. An ultrasonic flow meter according to claim 5, characterized in that the energy in the side lobes is captured and absorbed in an inner coating of the measuring tube of the flow meter, which inner coating is of a material in which sound propagates at a velocity that is approximately equal to or smaller than the sound velocity in the fluid to be measured and which exhibits a relatively high internal acoustic damping.

7. An ultrasonic flow meter according to claim 6, characterized in that the ends of said inner coating are spaced such a distance from the transducers that the side lobes fall outside the circumference of the inner coating, where said side lobes die in acoustic spaces provided for this purpose.

8. An ultrasonic flow meter according to claim 6, characterized in that said inner coating is a loose tube centred by means of centring shoulders on the transducers, which tube is provided with apertures in its wall adjacent the transducers for permitting the fluid to be measured to flow into and out of the tube, and which tube is externally provided with a sealing means, such as an O-ring,

for dividing the flow meter into two compartments and thereby preventing the fluid from bypassing said tube.

9. An ultrasonic flow meter according to claim 5, characterized in that said meter is made entirely of a material in which sound propagates at a velocity that is approximately equal to or smaller than the sound velocity in the fluid to be measured and which exhibits a relatively high internal damping.

10. An ultrasonic flow meter according to claim 9, characterized in that the connecting pieces for connecting the flow meter to components of the circuit through which the fluid to be measured flows are of a different, strong material, such as a metal.

11. An ultrasonic flow meter according to claims 5-10, characterized in that said material for the inner coating or the entire meter is polysulfon.

12. An ultrasonic flow meter according to claims 5-10, characterized in that said material for the inner coating or the entire meter is PTFE.

13. An ultrasonic flow meter according to claims 5-10, characterized in that said material for the inner coating or the entire meter is polyamide.

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FIG.1

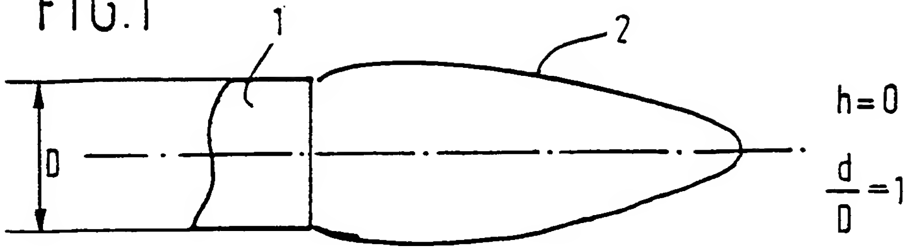


FIG.2

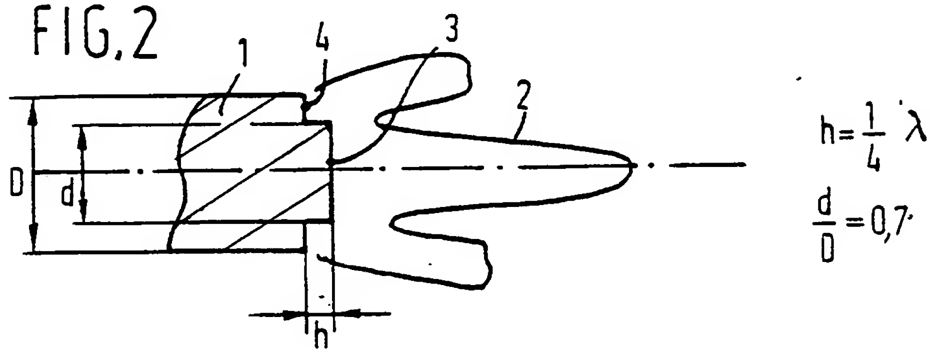


FIG.3

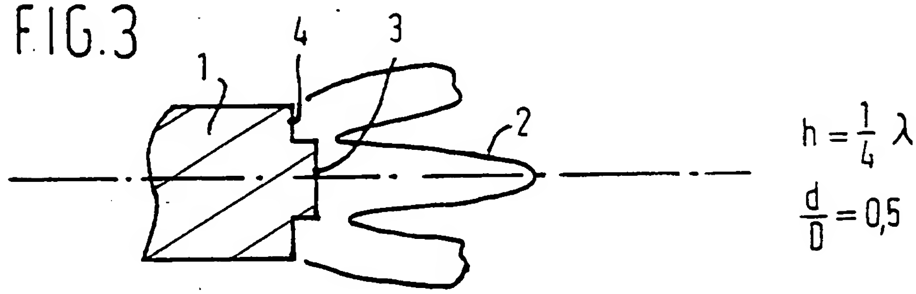


FIG.4

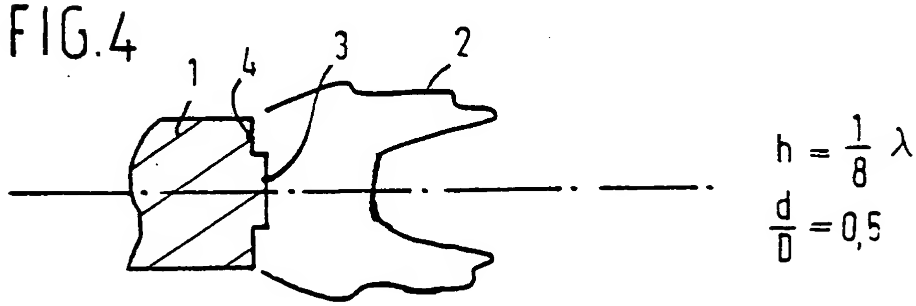


FIG.5

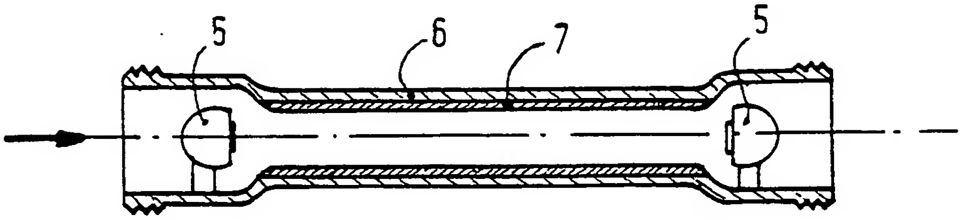


FIG.6

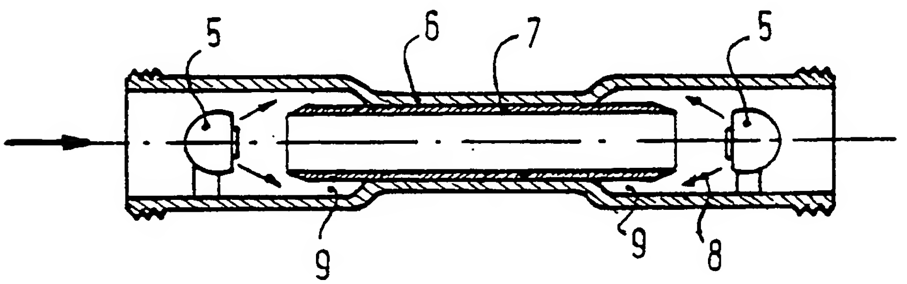


FIG.7

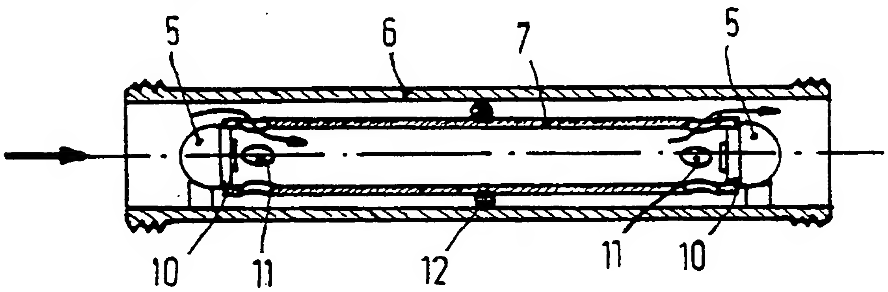
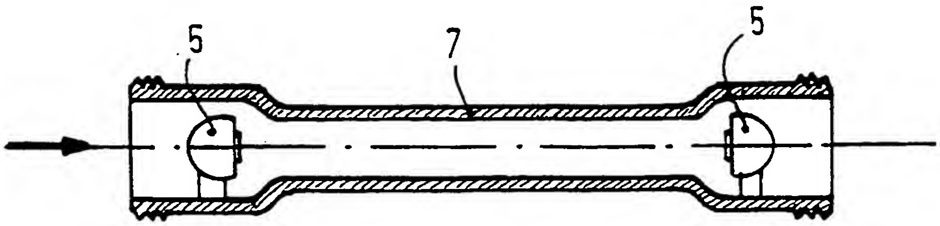


FIG.8



INTERNATIONAL SEARCH REPORT

International Application No PCT/NL 85/00041

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [8]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: G 01 F 1/66; G 10 K 11/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	G 01 F G 01 N G 01 K G 01 P

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	GB, A, 2011219 (EMI LTD.) 4 July 1979, see figures; abstract; page 1, lines 29-32,46-69; page 2, lines 34-46 --	1-2
A X	EP, A, 0088235 (LANDIS & GYR AG) 3 February 1983, figures; page 1, lines 31-37; page 2, line 6 - page 3, line 10 --	3 5-9
A	US, A, 2912856 (KRITZ) 17 November 1959, see figures; column 1, lines 46-67 --	1
A X	FR, A, 2369566 (DANFOSS A/S) 26 May 1978, see figures; page 3, lines 6-36; page 4, lines 6-13 --	1 5,6,13
A	EP, A, 0108852 (F. RITTMEYER AG) 23 May 1984, see figures; abstract --	1
X	US, A, 4081786 (M. RICHARD) 28 March 1978, see figures; abstract; column 2, lines 35-47 --	3

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
13th January 1986	05 FEV. 1986
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	G.L.M. Kruydenberg

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International Application No. PCT/NL 85/00041

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	GB, A, 2017914 (FLOWMETERING INSTR. LTD.) 10 October 1979, see figure 2	3,4
	--	
A	US, A, 4420707 (VAN VALKENBURG) 13 December 1983, see figure; abstract	3,4

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/NL 85/00041 (SA 11019)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 27/01/86

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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
GB-A- 2011219	04/07/79	None		
EP-A- 0088235	14/09/83	JP-A-	58153117	12/09/83
		DE-A,C	3211021	15/09/83
		US-A-	4480486	06/11/84
US-A- 2912856		None		
FR-A- 2369561	26/05/78	DE-A-	2748440	11/05/78
		SE-A-	7711987	28/04/78
EP-A- 0108852	23/05/84	None		
US-A- 4081786	28/03/78	None		
GB-A- 2017914	10/10/79	LU-A-	81093	19/06/79
		BE-A-	875194	16/07/79
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US-A- 4420707	13/12/83	None		

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